COLORED STONES
ASSIGNMENT 4
THE DURABILITY OF GEMSTONES... THE CONTROLLING FACTORS
IDENTIFICATION, PRODUCTION, MARKETING, BUYING

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(Note: The durability of gemstones depends on hardness, toughness and stability. These subjects will be considered individually in the order given.)

HARDNESS

I. INTRODUCTION.

Hardness is the resistance a gemstone or other material offers to scratching or abrasion. To the public (and, unfortunately, to many jewelers) hardness is the means by which gemstones are identified. Actually, the value of hardness to the gemologist is strictly limited. The information gained by this test is often of doubtful value, and the danger of defacing or even breaking a valuable stone is much too great to permit its indiscriminate use in gem testing.

The basic idea of hardness is that a harder stone will scratch a softer one, if a sharp point or an edge of the harder material is drawn across the softer one. Thus diamond scratches ruby, ruby scratches topaz, topaz scratches quartz, etc. Hardness is related to the strength of the bonds between the atoms in a stone. If the bonds are relatively strong, the stone is relatively difficult to scratch because of the resistance it offers to the tearing out of large numbers of atoms by the hardness point.

A gemstone may be very hard but comparatively fragile. If struck a sharp blow parallel to a direction of weakness, even a diamond will cleave readily. More fragile gemstones, such as emerald or zircon, may fracture without receiving violent blows. Zircon and emerald are hard, but they are low in a scale of relative toughness. Thus hardness has to do only with resistance to scratching, not with resistance to breakage.

II. DEGREES OF HARDNESS.

Many years ago Mohs, a German mineralogist, proposed a table that is still known and referred to as MOHS' SCALE OF HARDNESS, which is:

Talc	1	Orthoclase	6
Gypsum	2	Quartz	7
Calcite	3	Topaz	8
Fluorite	4	Corundum	9
Apatite	5	Diamond	10

This scale has been the source of great misunderstanding in the jewelry business and has caused much false information to be given to customers. It is NOT a scale in which the numbers indicate equal divisions of hardness, such as the divisions of inches on a ruler indicate equal divisions of distance. The intervals of hardness between these numbers are NOT EQUAL. The scale means that ORDINARILY a mineral of hardness 9 will scratch a mineral of hardness 8, that one of 7 will scratch one of 6, etc. Likewise, two substances of the same hardness will scratch each other equally well. This scale is valuable when testing the RELATIVE hardness of gem materials. The accompanying table shows the relative hardness of the common gem minerals and related substances and lists average values; most of these materials, however, vary slightly from the average values shown.

Mohs' scale might easily confuse the jeweler as well as the public. Actual grinding tests have resulted in statements that diamond is 90 times harder than corundum (ruby and sapphire), that corundum is at least five times harder than topaz, and that topaz and quartz show but little difference in hardness.

More reliable tests conducted at the National Bureau of Standards with a Knoop indentor hardness tester have shown that diamond has an indentation hardness of about five times that of corundum. Results of these tests have shown that if the top four minerals of Mohs' scale were listed on a true comparative basis, they would have the following values: diamond 46, corundum 9, topaz 8, quartz 7.

III. VARIATIONS IN HARDNESS.

Careful tests reveal that the hardness of any crystal substance may vary on different crystal faces. Even the same face of a crystal may show a difference in hardness when scratched in different directions. This might be compared with a piece of wood that shows a different hardness with the grain and against the grain. All cutters recognize the greater hardness of a diamond crystal parallel to the octahedral face, as compared with the hardness in any other direction. It is important to remember that a cut stone may show a variation in hardness on different facets and in different directions on the same facet. Slight variations in the hardness of different varieties of the same species are also found. For example, emerald is near 7 1/2 on Mohs' scale and aquamarine is 8, although both are beryl.

IV. LIMITATIONS OF HARDNESS.

Before considering the application of hardness tests to gem identification, it is essential to make clear their relative value. Hardness tests were useful in the days before optical tests were developed to their present high degree of accuracy. Although hardness still has some limited uses in gem identification, for the most part it has been replaced with more positive methods that cannot possibly harm a stone. Thus hardness tests are taboo for the identification of faceted stones. However, they still have some limited uses when testing an occasional opaque gemstone and in the testing of rough material.

An interesting use of hardness points or a steel file on a faceted stone is that employed by some pawnbrokers when they suspect a customer of trying to pass off an imitation as a diamond: They attempt to place an obvious scratch across the table of the stone to protect less observant members of the pawnbroker's fraternity. Obviously, this is a dangerous practice, for a genuine stone may be cleaved; or if the customer has made an honest mistake, serious consequences are probable. This, however, is an unusual use for hardness.

The major reason for this discussion of hardness is to point out the relative wear resistance of the important gemstones. Secondary reasons relate to dispelling misconceptions about hardness, and to indicate how hardness plates and points may be used in the testing of rough gemstones and opaques.

The danger of testing transparent stones by hardness cannot be overemphasized. Jewelers frequently send to one of the GIA laboratories stones belonging to customers on which hardness tests have been made, with the result that recutting was mandatory. In no case was a hardness test of value in identifying these stones. As an illustration of the insignificant and decreasing use of hardness in testing, the GIA laboratories annually test thousands of transparent stones without ever resorting to a hardness test. On opaque pieces, such as badly worn or poorly polished cabochons, hardness tests are used on occasion. Unfortunately, hardness tests are used frequently by poorly equipped geologists with a smattering of mineralogy. The GIA laboratories have tested many stones supposedly tested by government or university scientists as over 9 in hardness (and thus presumably diamonds) that were actually quartz. The harder the stone and the smoother the surface, the more likely are overestimates of hardness.

V. TESTS FOR RELATIVE HARDNESS.

The object of hardness tests is to determine what mineral on Mohs' scale is most nearly equal to the hardness of the gemstone being tested. Any gemstone that is approximately the hardness of quartz (7) is said to be 7 in hardness, but if it tests between two of the minerals on the scale, it is expressed by 1/2. Thus a gemstone that tests harder than quartz but softer than topaz is said to be 7 1/2 in hardness.

In addition to Mohs' scale, it is well to know that tests of relative hardness can be made by the following objects, which have the individual hardness values shown:

Fingernail	2 1/2 or under
Copper coin	3
Steel file	6 to 7
Knife blade	5 1/2 or under
Window glass	5 1/2

HARDNESS POINTS are merely metal stems on the ends of which have been mounted small crystals or fragments of minerals. The materials most commonly used are Carborundum (9 1/4), corundum (9), topaz (8), quartz (7), feldspar (6). When testing with hardness points or a steel file, the point of the instrument should be applied to the back of the stone with a very firm but fairly light pressure. Be sure that the stone is held in such a way that there is no danger of breaking it. Many opaque cabochons are very flat; therefore, if such a stone is held between the fingers and the point applied to the center of the back, the resultant stress may cause it to split. It is obvious that the point should be applied to the back rather than the top, for even an unnecessarily large scratch will not be visible when the stone is mounted. But it is wise to apply the point at a place where the finger is supporting the stone. In addition, it should not be close enough to the edge to cause chipping when the point is applied.

The hardness point should be held erect and more or less perpendicular to the surface being tested in order to avoid the danger of breaking the point. The point is then drawn across the surface very carefully for a distance of only about 1/32 to 1/16 of an inch. The feel of a file or hardness point as it "bites" into a softer substance or slides over a harder surface soon becomes familiar, as does the sound of each.

Either file or point often leaves a STREAK of itself on a slightly rough surface. To distinguish between a streak and a scratch, rub the surface and examine it with a loupe. A scratch will form a depression that is still evident after the powder has been rubbed away. The term streak also refers to the powder left by a mineral when drawn across rough porcelain, the color of which may be characteristic for that mineral. For example, the red-brown color of the hematite streak provides a means of separating this mineral from its numerous substitutes.

HARDNESS PLATES are sometimes used instead of points for testing. These plates are merely polished sections of the minerals of Mohs' scale. The stone to be tested is pressed firmly against the plate and moved about 1/16 of an inch. The plate is then observed to determine whether a scratch was made. Obviously, hardness plates are less likely to injure a stone than are points. However, if hardness plates are used without care, the girdle of the stone may be damaged. A short time ago a student sent a fine tourmaline to the Institute that he had tested on a hardness plate. The damage to the girdle was sufficient to require recutting the entire stone. Hardness plates with sharp corners are sometimes used in place of hardness points.

TOUGHNESS

I. INTRODUCTION.

Toughness may be defined as the resistance a gemstone offers to breakage. In practice this is considered to include resistance to chipping and cracking as well as actual breakage. If a gem has a low degree of toughness, it is impractical for many uses and its value is reduced accordingly. A gemstone that breaks very readily is said to be FRAGILE.

A stone may be very tough and not extremely hard, or vice versa. But a mineral is not suitable for use as a gemstone if it separates so easily that it is almost entirely lacking in toughness. A diamond is extremely hard but not exceptionally tough. Fluorite is neither hard nor tough and is therefore fragile. Nephrite is not hard but it is extremely tough. Stones that are very tough may wear better than much harder stones. The qualities of hardness and toughness must not be confused.

II. COHESION.

All substances are considered to be composed of small particles called ATOMS. These minute particles are held together by a force of attraction called COHESION, which tends to resist any separation between the atoms. When a substance is broken it is done by a force that overcomes this attraction. Thus the stronger the cohesion, the greater will be the effort necessary to break the substance.

ELASTICITY is the ability of minerals to undergo a certain amount of distortion when under pressure and yet return to the original form when the pressure is released.

Some minerals (metals) may be cut (SECTILE), hammered flat (MALLEABLE or drawn into wire (DUCTILE).

BRITTLENESS refers to a lack of ability to withstand distortion without separation. Minerals that break or powder, instead of bending or flattening out when struck with sufficient force, are said to be BRITTLE. Thus brittle does not necessarily mean easily broken; it only means that a mineral finally powders rather than flattening as a metal does under enough blows. All important gem minerals are classed as brittle minerals, which are subdivided as follows: FRIABLE (easily separated into grains, SOFT (easily powdered) and TOUGH (offering some degree of resistance to separation). Toughness in gemstones is classed as EXCEPTIONAL, EXCELLENT, GOOD, FAIR OR POOR.

III. CLEAVAGE.

The distinguishing feature of crystalline materials is the regularity of the arrangement of atoms. In many gemstones the pattern is such that the spacing of atoms in different directions is substantially the same. When such a stone is broken, the break is likely to take whatever path will relieve the stress that caused the break. In other gemstones the arrangement of atoms is such that some planes have concentrations of atoms, with wider spaces between these planes. In this event, a break in a stone is likely to occur parallel (i.e., between) the planes of concentrated atoms (Figure 1). Depending on the symmetry in the crystal system and the directions in which atoms are more closely packed, there may be six, four, three or two directions of cleavage or only one direction. The cleavage of a mineral is classed as PERFECT, DIFFICULT, EASY, etc.

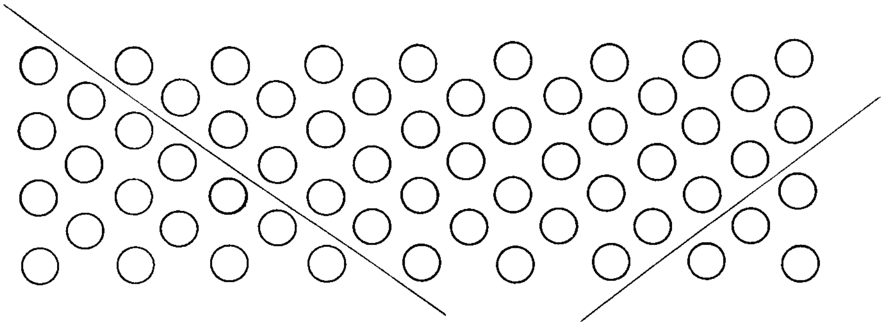

FIGURE 1.

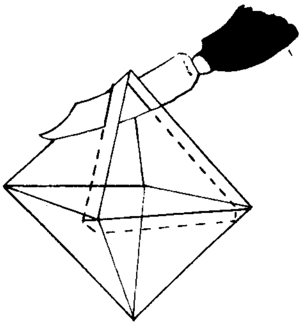

FIGURE 2.

A more concise definition of cleavage and its characteristics would be: Cleavage is the tendency of a crystalline mineral to separate in certain definite directions producing flat, smooth surfaces. The planes in which it occurs are called CLEAVAGE PLANES. Since these correspond to definite atomic planes, they will be parallel to a possible crystal face of a crystal form in which that mineral might occur. For example, diamond occurs in several different forms characteristic of the cubic system; however, the atomic planes in which an easy separation may be effected are parallel to the faces of the octahedron form. Thus diamond is said to have OCTAHEDRAL CLEAVAGE (Figure 2). (Note: In the stone samples that accompany this course, notice the excellent three-directional cleavage in calcite.) The cleavage planes in diamond are often referred to as the GRAIN.

A separation involving cleavage does not always produce absolutely smooth surfaces, but may exhibit tiny "ledges," or a steplike appearance, resulting from a combination of alternate cleavages and fractures or cleavages in different directions. Some minerals cleave easily in directions that parallel the faces of more than one crystal form.

FALSE CLEAVAGE, or PARTING, is a separation somewhat similar to cleavage. It frequently occurs along planes between laminae due to repeated twinning, thus differing from true cleavage, which occurs between atomic planes. Parting often occurs only in certain specimens of a gem species. Among important gem minerals, it occurs only in corundum, where it is seldom sufficiently pronounced to affect toughness or to either assist or interfere with fashioning.

When a cutter knows the direction of the cleavage plane and the "cleavage is good," a slight cutting, followed with a wedging strain, will accomplish the splitting. Cleavage was once important in diamond fashioning, but it has been largely replaced by sawing. Flawed portions of a diamond crystal can often be cleaved off with very little loss of material. Cleavage is so well developed in some gemstones that they must be handled with extreme care. A sharp blow or rapid changes in temperature, such as might occur during cutting and polishing, may start cleavage cracks and lessen the beauty and value of a gem. Also, once the slightest cleavage is apparent, the flaw may increase with hard usage.

IV. FRACTURE.

The term FRACTURE is used to describe the chipping or breaking of a substance in any direction OTHER than that of a cleavage plane (Figure 3).

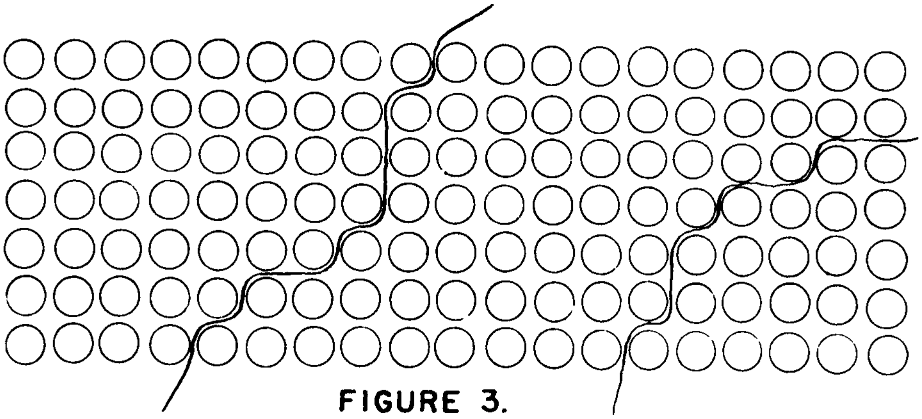

FIGURE 3.

A CONCHOIDAL (pronounced kon-KOY-dal), or SHELL-LIKE, fracture is the term used to describe breakage that produces curved ridges similar to the outside markings on a shell. A typical conchoidal fracture occurs when glass and most transparent colored stones are chipped.

GRANULAR, SPLINTERY, UNEVEN AND EVEN are terms used to express the appearance of other types of fracture. A granular fracture is typical of crystalline aggregates; for example, the broken surface of a lump of sugar. Splintery is used to describe a break with a fibrous appearance. An even fracture approaches the smoothness of a cleavage. An uneven fracture includes any break not covered in the above descriptions and may be irregular, jagged, etc.

It has been customary in the trade to refer only to breakage on the girdle or on facet junctions as fractures. However, fractures may be on the surface of a gem, where they are sometimes known as PITS, or in the interior, where they are often called FLAWS or FEATHERS. The term CHIP is often used to describe surface fractures, especially on the girdle.

V. FLAWS.

Flaws such as fractures and cleavages spoil the transparency of a stone and lower its value. When they are observed, special care should be taken when setting or otherwise subjecting the gem in which they occur to possible blows or pressure. Another kind of imperfection that can increase the possibility of separation is INTERNAL STRAIN. This can be the result of improper crystallization or inclusions that tend to distort the structure of the gem. The detection of internal strain will be discussed under the subject of optical properties.

VI. THE EFFECTS OF CLEAVAGE AND FRACTURE.

A few stones cleave so easily that their desirability as gems is affected. For instance, genuine topaz (not topaz quartz), when set in rings that receive exceptionally rough usage, may prove unsatisfactory because it cleaves easily. Many varieties of zircon fracture easily, and even in ordinary wear as ring stones they crumble or fracture along the edges of the facets or even on the facet surfaces themselves.

Some gem minerals fracture easily but do not cleave easily; for instance, zircon or emerald. In others, cleavage is more likely to occur than fracture; topaz or diamond, for example. However, if one is familiar with their characteristics and exercises care in their wear, there is but slight chance of serious damage to any gemstone. It is the responsibility of the salesman from whom a gem is purchased to acquaint the purchaser with any of the ordinary properties in which it is in any way deficient.

VII. HOW CLEAVAGE AND FRACTURE MAY BE USED.

Cleavage is important to both the lapidary and the diamond cutter, but for different reasons. Because of the extreme hardness of diamond, shaping the rough before faceting is difficult. Cleavage provides a means of separating large diamond crystals into better shapes or sizes. The lapidary, who works with softer gemstones, finds cleavage something to guard against rather than to use. Some gemstones (kunzite, for example) have such easy cleavage that it is exceedingly difficult to cut.

Experienced gemologists can often obtain an indication of the identity of a stone by the direction and nature of a cleavage crack or by the shape and luster of fractures, but considerable handling of many and various stones is necessary for one who wishes to depend on these as an aid in identification. Of course, such a test is limited because the majority of stones do not cleave easily nor display characteristic fracture surfaces. In fact, most gemstones display a conchoidal fracture with a VITREOUS (glasslike) luster. The important exceptions are listed in the table accompanying this assignment, and include such examples as turquois and its best imitation, glass. Both turquois and glass exhibit a conchoidal fracture, but the luster of the fracture surface of glass is vitreous and that of turquois dull or earthy, similar to that of unglazed porcelain. Since almost any cabochon will have minute fractures around the girdle, this becomes a valuable test. Glass is used also to imitate "black onyx" and other varieties of chalcedony (quartz). Although chalcedony, like glass, displays a conchoidal fracture, the luster of the fracture surfaces of chalcedony are waxy rather than vitreous.

Cleavage is less valuable in identification, but, like fracture, the presence of tiny cleavages can sometimes be of assistance. For example, some varieties of chalcedony (e.g., "California moonstone") bear a close resemblance to certain types of feldspar. Any chips or breaks along the girdle of the precious moonstone (feldspar) will display tiny flat cleavage surfaces. These may or may not be observed easily, depending on the general direction of the break. If the break closely parallels the cleavage planes, the exposed surface will be flat; if it crosses the cleavage planes at an angle, the exposed surface will have a steplike appearance, resulting from a combination of alternating cleavages and fractures.

STABILITY

The third aspect of durability, in addition to hardness and toughness, might be called STABILITY. It relates to the ability of a gemstone to resist loss of color, dissolution by chemicals, or other forms of deterioration. For example, pearl is damaged by fairly weak acids, some turquois tends to become greenish when it absorbs skin oils and acids, and a number of gems tend to fade in color over a period of time. However, most of the important gems are very stable, since they resist even concentrated acids and do not lose color.

The stones that may give trouble include heat-treated zircon (which tends to revert to a brownish color), some amethyst and kunzite (both of which tend to fade), plus turquois and pearl (for the reasons mentioned above). With the exception of those changes involving loss or change of color, avoiding deterioration requires only a need to take care of the stones--not reasons for avoiding their use as gemstones.

THE SIGNIFICANCE OF DURABILITY

Although durability is listed in Assignment #1 as a prerequisite of a material in order to be considered a gemstone, a study of the variations in hardness and toughness among the important gemstones makes it clear that the durability requirements are not very great. A gemstone may be fairly fragile but very popular. For example, opal is one of the most cherished of stones and certainly one of the most widely sold, yet it is neither hard nor tough. It is among the softest and most fragile, although it is probably slightly harder than the average nongem mineral. However, the important thing is that a gem must be sufficiently resistant to surface wear and breakage to be practical for use in jewelry. What the lower limits are in these two durability categories is hard to say, but it is certain that if the wearer is willing to exercise the care necessary to protect his gemstone from damage, almost any hardness is not too low. By a similar reasoning, almost any stone that can be cut effectively is tough enough to wear in a protected setting, if it is worn with care. For example, an early graduate of the Institute has worn an opal tie pin for about fifty years without repolishing and it is as lovely as ever. There are a number of items worn or used for the purpose of beautification that are much less durable than even a fragile gemstone, yet there is certainly a lower limit to the hardness and toughness of a gem that is practical for use in jewelry. This practical lower limit for use in rings is considerably higher than that for use in pins, earrings and other pieces that are likely to receive less abuse.

A common fallacy among jewelers regarding the durability of gemstones is to confuse hardness and toughness. It is believed that a hard stone must be tough and that a stone low in hardness must be fragile. This is far from the truth. For example, although pearls are 4 or less in hardness, they are so tough that many are used in rings. A low hardness means only that the surface will become abraded at a rate dependent on how low the hardness is, plus the care it is given. Actually some gemstones are very hard but fragile. If diamonds are poorly seated in a mounting, with unequal pressure applied by the prongs, cleavage is likely. If a blow is delivered at the right angle, it does not have to be very sharp to cause cleavage. Topaz is notably fragile, for its cleavage is rather easily developed. Zircon and emerald are also quite fragile, for they fracture easily. Consideration of the difference between hardness and toughness makes the relationship clear. If a gem is tough but not hard, its surface may be dulled over a period of time, but it may be repolished easily. A lack of toughness, on the other hand, threatens the life of a gemstone, since it may be broken during ordinary wear. Low hardness has a greater effect on some types of gem material than it has on others. If a gem is desirable chiefly because of its color, an abraded surface has less effect on its beauty than if it is cherished for other attributes that require a fine surface for effectiveness. For example, the jades are not materially affected by a slightly dulled surface, but a moonstone of equal hardness is much less attractive when its surface has become abraded.

It is extremely important that gem salesmen, lapidaries, stonesetters and jewelry repairmen understand the durability of various gemstones. Of course, no gem should be abused by its wearer. Yet when selling stones that require particular care, an explanation of the reason for the special protection will rarely affect their salability but will avoid later dissatisfaction. Wearers of easily damaged furs or light-colored clothing do not hesitate to buy them for their beauty alone, even though they require special care.

Many mis-statements are made to the effect that diamond cannot possibly be abraded by other minerals. This disagreement is probably based on the improper use of the terms SCRATCH and ABRADE. It is true that it requires a sharp edge of a diamond to make a visible scratch across the surface of another diamond; however, diamond can be slowly abraded by softer materials. Diamonds used in industry for their extreme hardness are slowly worn down in contact with the much softer materials. For example, diamond dies through which wire is drawn are slowly enlarged by long use for this purpose, and are enlarged to different gauges in successive steps as they become too large for use with the original gauge size with which they started. Diamond tools are also used to true abrasive wheels of silicon carbide. However, diamond is so much harder than even silicon carbide that those set in tools used to true abrasive wheels often last long enough to true thousands of such wheels.

The most obvious dividing line between the hard and soft gemstones is at 7 on Mohs' scale. The reason for this is the fact that quartz (hardness 7) is the most common of minerals and is an important constituent of ordinary dust. As a result, the simple act of wiping the dust from a gem of 7 or softer, causes an accumulation of minute abrasions that will eventually dull the surface. This suggests that dust should be brushed lightly from the surface of such a gem or blown from it, not wiped off. However, even those stones on which the surface has become dulled by abrasion can be repolished at low cost.

RELATIVE HARDNESS

OF THE COMMON GEM MINERALS

AND RELATED SUBSTANCES

Asterisks (*) indicate other than gem substances. Where two numerals appear, the hardness varies between those two figures.

Diamond	10
Corundum	9
Synthetic Corundum	9
Chrysoberyl	8½
Spinel	8
Synthetic Spinel	8
Topaz	8
Beryl	7½ - 8
Synthetic Emerald	7½ - 8
Almandite (Garnet)	7½
Zircon	7 - 7½
Rhodolite	7 - 7½
Pyrope (Garnet)	7 - 7½
Tourmaline	7 - 7½
Spessartite (Garnet)	7 - 7½
Grossularite (Garnet)	7
Quartz	7
Chalcedony (Quartz)	6½ - 7
Synthetic Rutile	6½ - 7
Peridot or Olivine	6½ - 7
Jadeite (Jade)	6½ - 7
Andradite (Garnet)	6½ - 7
Spodumene	6 - 7
Steel File*	6 - 7
Marcasite	6 - 6½
Pyrite	6 - 6½
Microcline (Feldspar)	6 - 6½
Orthoclase (Feldspar)	6 - 6½
Oligoclase (Feldspar)	6 - 6½
Nephrite (Jade)	6 - 6½
Labradorite (Feldspar)	6
Iridium*	6
Hematite	5½ - 6½
Opal	5½ - 6½
Glass	5 - 6 3/4
Strontium Titanate	5 - 6
Lapis-Lazuli	5 - 6
Turquoise	5 - 6
Natural Glass	5½
Tooth Enamel*	5
Palladium*	4½
Iron*	4 - 5
Platinum*	4 - 4½
Brass*	4
Shell	3½
Coral	3½
Jet	3 - 4
Copper Coin*	3
Pearl	2½ - 4
Ivory	2½
Tortoise-Shell	2½ - 3
Silver*	2 - 2½
Amber	2 - 2½
Gold*	2 - 2½
Plastic Group*	1½ - 3
Lead*	1½
Talc	1
Graphite	1
Wax	¼

CLEAVAGE, FRACTURE AND RELATIVE TOUGHNESS OF THE COMMON GEM MATERIALS

The following classification of gems, LISTED IN ORDER OF DECREASING toughness, is divided into two groups, as shown below in the left-hand column: (1) faceted transparent stones and (2) cabochon-cut translucent to opaque stones (generally crystalline aggregates). It is not possible to make a direct comparison between these two basic classifications, since too many unrelated factors are involved. For example, nephrite jade, if fashioned with a thin girdle similar to that on most diamonds, would stand little abuse without chipping, whereas a cabochon with a thick girdle would be exceptionally resistant to breakage. Among both of these groups are extreme variations in each species, since the number and nature of flaws, perfection of structure, and purity of composition all have a marked effect on comparative durability. Some diamonds with no visible flaws have been known to shatter under temperature changes alone without pressure being applied. This is in marked contrast to the usual good durability of most diamonds. Thus, when considering the relative durability of any species, including diamond, it must be remembered that some specimens of that species may be broken more easily than others.

Order of Decreasing Toughness	Cleavage	Fracture	Luster of Fracture
(Group #1)			
Corundum (Syn. & Natural)	None	Conchoidal	Vitreous to Subadamantine
Diamond	Easy	Conchoidal	Adamantine
Spinel (Syn. & Natural)	None	Conchoidal	Vitreous
Chrysoberyl	None	Conchoidal	Vitreous to Subadamantine
Quartz	None	Conchoidal	Vitreous
Garnet	None	Conchoidal	Vitreous to Subadamantine
Tourmaline	None	Conchoidal	Vitreous
Synthetic Emerald	None	Conchoidal	Vitreous
Beryl	None	Conchoidal	Vitreous
Topaz	Easy	Conchoidal	Vitreous
Peridot	Indistinct	Conchoidal	Vitreous to Subvitreous
Zircon (heat treated)	None	Conchoidal	Subadamantine
Spodumene	Easy	Splintery	Vitreous
Synthetic Rutile	None	Conchoidal	Vitreous
Glass	None	Conchoidal	Vitreous
Strontium Titanate	None	Conchoidal	Vitreous
(Group #2)			
Nephrite	None	Granular	Dull
Jadeite	None	Granular	Dull
Plastics	None	Conchoidal	Vitreous, Resinous, Dull
Chalcedony	None	Conchoidal	Waxy to Dull
Hematite	None	Splintery	Metallic to Dull
Lapis-Lazuli	None	Granular	Dull
Coral	None	Uneven	Dull to Waxy
Pearl	None	Uneven	Pearly to Dull
Shell	None	Splintery	Dull
Turquois	None	Conchoidal Granular	Waxy to Dull

(OVER)

Order of Decreasing Toughness	Cleavage	Fracture	Luster of Fracture
Labradorite	Easy	Splintery	Vitreous to Pearly
Microcline	Easy	Splintery	Vitreous to Pearly
Orthoclase	Easy	Splintery	Vitreous to Pearly
Malachite	None	Uneven	Dull
Glass	None	Conchoidal	Vitreous
Amber	None	Conchoidal	Resinous
Opal	None	Conchoidal	Subvitreous